

OCCASIONAL PAPERS

Rethinking the Roots of Modern Science: *Arabic Manuscripts in European Libraries*

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Rethinking the Roots of Modern Science:

Arabic Manuscripts in European Libraries

Several widely accepted assumptions govern the scholarship of those studying the historical relationship between Arabic science and the Latin West. The first is the belief that the main role played by Arabic-writing* scientists simply to preserve Greek classical science, with original Arabic scholarship contributing little. The second is that the translation of Arabic texts into Latin ended by the thirteenth century at the latest. And the third is that Renaissance science represented both a break with the mentality of medieval science and an effort to recapture the sciences of antiquity. Within this framework it is assumed that Renaissance intellectuals had a low opinion of medieval science and its Arabic origins and insisted instead on going back to the "pure" Greek sciences. Astronomy, the queen of ancient and medieval sciences, is thought to have continued to reign supreme during the Renaissance, as witnessed by the use of such concepts as the Copernican revolution, usually applied to the new Renaissance sciences and, by extension, often used to characterize the emergence of modern science.

These presuppositions, mainly arrived at during the nineteenth century, remain well entrenched despite overwhelming recently gathered evidence to the contrary. At times, as we shall see, these assumptions give rise to real paradoxes.

*This terminology is used to refer to the complex phenomenon whereby scientists of Islamic civilization wrote in Arabic even though they were ethnically Persian, Turks, etc., and did not necessarily speak Arabic at home.

RECENT RESEARCH

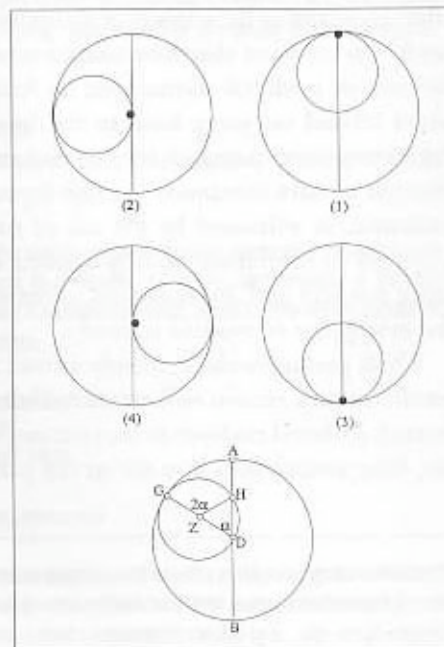
I would like to preface my critique of this received knowledge with a review of findings of the last 40 years or so in the history of astronomy.

Between 1957 and 1968 the distinguished historians of science, Otto Neugebauer and Edward S. Kennedy, established a connection between Copernican and Arabic astronomy, demonstrating that the lunar model described by Copernicus (1473-1543) was identical to the one stipulated by Ibn al-Shatir of Damascus (d. 1375) more than a hundred years earlier.¹

During the 1970s and 1980s scholars such as Noel Swerdlow, Willy Hartner, and myself, among others, took Neugebauer's and Kennedy's research a step further in a series of articles which explored the relationship between Copernican astronomy and its Arabic antecedents in greater depth. In 1973 Swerdlow could claim that Copernicus did not fully understand the models that he was describing when he wrote his *Commentariolus* in 1516. He went on to assert that

Figure 1. The Theorem now called the Tusi Couple.

It states that if two spheres, one twice the size of the other are arranged in such a way that they are tangent from inside at one point, as in case (1), and if the larger sphere is allowed to move in any direction at any speed, and the smaller one were to move in the opposite direction at twice that speed, then the point of tangency will oscillate back and forth along the diameter of the larger sphere. In the proof the point of tangency is designated with the letter *H*.



Copernicus must have been working from a model developed by another scholar, probably that of Ibn al-Shatir.²

In the same year, Hartner advanced the argument by demonstrating that one of the pivotal mathematical theorems in Copernican astronomy (figure 1) had been proven for the first time some 300 years earlier by Nasir al-Din al-Tusi (d. 1274). Copernicus had not only used the theorem, known as the Tusi Couple, but had gone so far as to use the same alphabetic designators for geometric points that Tusi deployed in the statement and proof of his theorem (figure 2). That is to say, where Tusi had used the Arabic letter *alif* to designate a specific geometric point in his theorem, Copernicus used the phonetically equivalent Latin letter A to designate the same point; and where Tusi used the Arabic letter *bā*, Copernicus rendered the same point B.³

In 1984, I established that in his model of the upper plan-

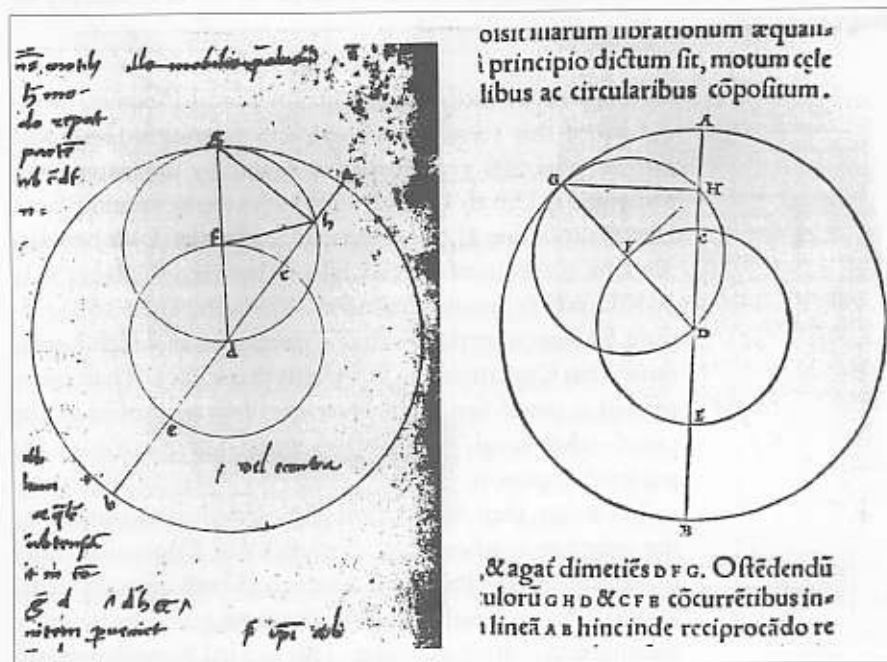


Figure 2. The Tusi Couple as it appears in the works of Copernicus, both in manuscript and printed forms, using the same lettering, and referred to by Willy Hartner, "Copernicus, the Man, the Work, and its History," *Proceedings of the American Philosophical Society*, vol. 117, no. 6, (1973), pp. 413-422, esp. p. 422. [Courtesy of the American Philosophical Society.]

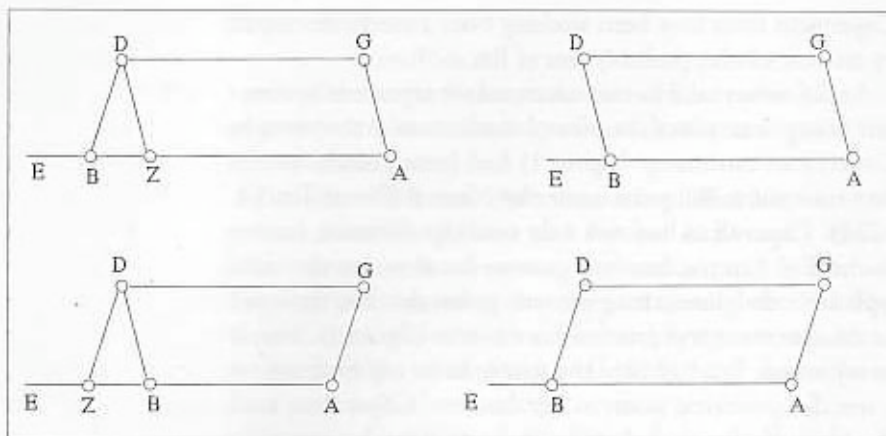


Figure 3. 'Urdu's Lemma. The theorem was first proved before 1250 AD by Mu'ayyad al-Din al-'Urdu (d. 1266). It states that if two lines AG and BD that are equal in length are set with extremities along a line AB , and if they form equal angles with respect to line AB , either internally or externally (in all conditions here illustrated), then the line GD joining their other extremity will always be parallel to line AB .

ets Copernicus used another mathematical theorem, without proof this time, which was also first introduced and proven some 300 years earlier in Arabic by the astronomer Mu'ayyad al-Din al-'Urdu (d. 1266) who worked mainly from Damascus (figure 3).⁴ This theorem, called the 'Urdu Lemma, was later the focus of correspondence between Kepler (1571-1630) and his teacher Maestlin (1550-1631) in 1595, almost 50 years after the death of Copernicus, in which Kepler noted that Copernicus had used this theorem, but had never offered a proof for it. In response, Maestlin offered the proof—that is, al-'Urdu's proof, not Copernicus—to his student⁵ (figure 4).

In essence, then, this historical research demonstrated that the only two mathematical theorems that Copernicus used to reformulate the Ptolemaic system had both been deployed 200 to 300 years earlier and for the same purposes by other astronomers writing in Arabic. This fact led Neugebauer and Swerdlow to conclude, in their now-classic 1984 work on the mathematical astronomy of Copernicus, that the work of Copernicus must be perceived as a continuation of earlier astronomical works written in Arabic, and that Copernicus

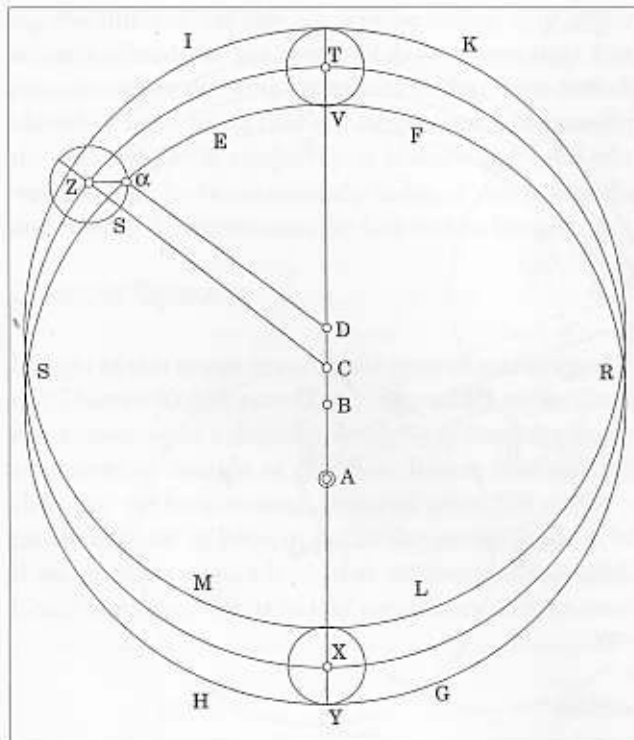


Figure 4: Redrawing of an application of 'Urdi's Lemma as it was deployed in the work of Copernicus and later appeared in the correspondence between Kepler and his teacher Maestlin, where it is proven that line αD will always be parallel to line ZC . [Courtesy of the American Philosophical Society.]

should rightly be seen as the last astronomer in that Arabic tradition.⁶

None of these Arabic-writing predecessors of Copernicus, it must be stressed, had worked from a heliocentric system. Heliocentricity, in its modern sense, was indeed first introduced by Copernicus. Shifting the center of the cosmos, from the earth to the sun, however, involves a rather simple reversal of the vector that connects the earth to the sun. The rest of the mathematical models remain the same. Indeed, Copernicus himself would normally first describe his models as geocentric, and then, after making all the modifications needed, would shift the center to the sun, a process that keeps all the connecting lines parallel to their original position (figure 5). It must be remembered that the postulation of a heliocentric world without the theory of universal gravitation to hold it together is still a real problem for Copernican studies.⁷

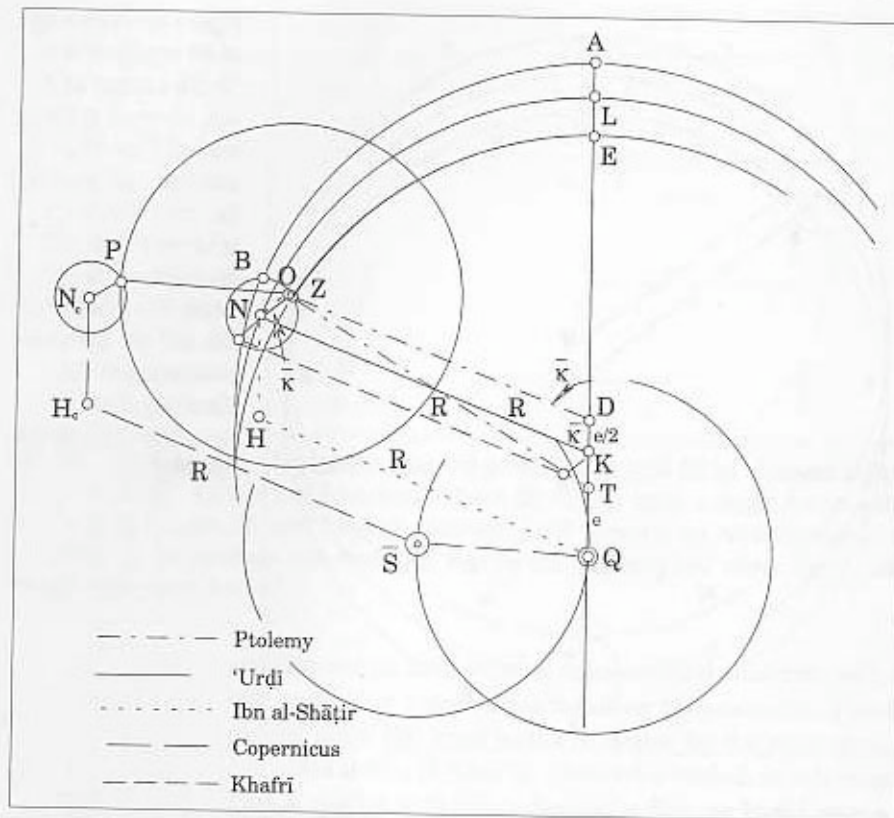


Figure 5. Diagram showing the modifications proposed for the model of the upper planets by a group of astronomers writing in Arabic (between 1250 and 1550) and by Copernicus (d. 1543), all superimposed over the model that was first proposed by Ptolemy (c. 150 AD). The diagram shows by parallel lines that all models would predict the position of a planet at point *P* for the observer on earth at point *Q* irrespective of any heliocentric or geocentric assumptions.

In addition to those specific findings about Copernicus' predecessors, this line of research has also developed a broader picture of the world of Arabic astronomy. It has, for example, revealed that the Arabic-speaking astronomers who produced the two theorems deployed by Copernicus were by no means unique. Rather, they belonged to a much larger group of astronomers who, as far as we can establish, were working between the eleventh and the fifteenth centuries, and were all engaged in the reform of Greek astronomy (figures 5 and 6).⁸

The period before the eleventh century and the one follow-

ing the fifteenth century are now becoming very important subjects of study for the history of Arabic astronomy. I anticipate that when the works produced during those periods are identified and studied they will deepen our understanding of the status of Greek astronomy in Islam, which until recently was assumed to be uncreatively stable, a status first shaken only during the Renaissance by Copernicus himself.

QUESTIONS GENERATED

In light of this recent research, we must reconsider and lay to rest Thomas Kuhn's paradigm theory which views Copernican astronomy as a dramatic break away from the dominant astronomical thought of the time. Recent findings make it clear that the breakthrough occurred some 200 to 300 years earlier, and not in Europe, but in the eastern lands of Islam. It was in those eastern lands that astronomers first criticized Greek astronomy for its lack of consistency with its own pre-

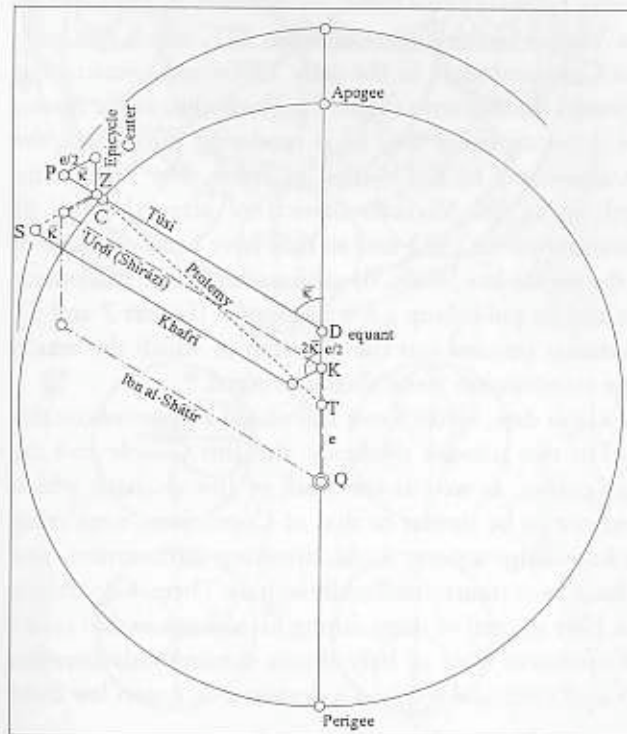


Figure 6. Detailed diagram of the modifications made for the model of the upper planets by five astronomers who wrote in Arabic between the thirteenth and the sixteenth century. All the modifications are superimposed over the model proposed by Ptolemy (c. 150) and all demonstrate that for an observer at point *Q* on the earth, the center of the epicycle at point *Z* will be imperceptibly close to point *C* required by Ptolemy's observations.

mises. Furthermore, we now know that the shift away from considering the universe as a mathematical construct unrelated to physical reality, toward the conceptualization of the world as a set of physical bodies subject to the same physical laws applicable on earth, was reached earlier still in the ninth century, when Muslim astronomers were raising these same questions.⁹

A major question, however, remains: How did Copernicus learn about these earlier Arabic theorems and use them, as he did, in exactly the same fashion and to the same purposes as did his Arabic-writing predecessors? There is no evidence that Copernicus could read Arabic, and no texts containing these theorems have been found in Latin, a language he did read. How then could these results have reached him? For a while, students of this episode thought that the most likely route would have been through Greek, for Copernicus did read that language, and Byzantine astronomers writing in Greek had some knowledge of late Arabic and Persian astronomy. Following this route, Neugebauer in 1975 identified a Vatican Greek manuscript, Gr. 211, which was written in Constantinople in the early 1300s and contained at least one of the theorems (figure 7). The author of the manuscript states explicitly that he is rendering into Greek the latest astronomy he has learned in Persia. The manuscript ended up at the Vatican sometime after the fall of Constantinople in 1453 and so may have been available in Italy during the late 1400s. By calling attention to this manuscript and by publishing a few pages of it (figures 7 and 8), Neugebauer pointed out the direction in which the search for the transmission route should proceed.¹⁰

At a later date, Neugebauer articulated a tentative conclusion. The two relevant theorems, the Tusi Couple and the 'Urdu Lemma, as well as the work of Ibn al-Shatir which turned out to be similar to that of Copernicus, were common knowledge among Arabic-speaking astronomers, and may have been transmitted orally to Italy. There, Copernicus might have learned of them during his sojourn in that country. Copernicus lived in Italy almost continuously between 1496 and 1503 and received a doctorate in canon law from

Ferrara in 1503. Sometime between 1508 and 1512 he conceived of his new astronomy and in 1516 published the *Commentariolus* in which he used the two theorems mentioned above (figures 1 and 3). As we have noted, Swerdlow, the editor of this early work of Copernicus, says that at that time Copernicus did not yet understand fully the models that he was describing.

Nearly 30 years later, in 1543, Copernicus published his most famous work, *De Revolutionibus*, in which both Tusi's and 'Urdi's theorems were fully utilized and apparently un-

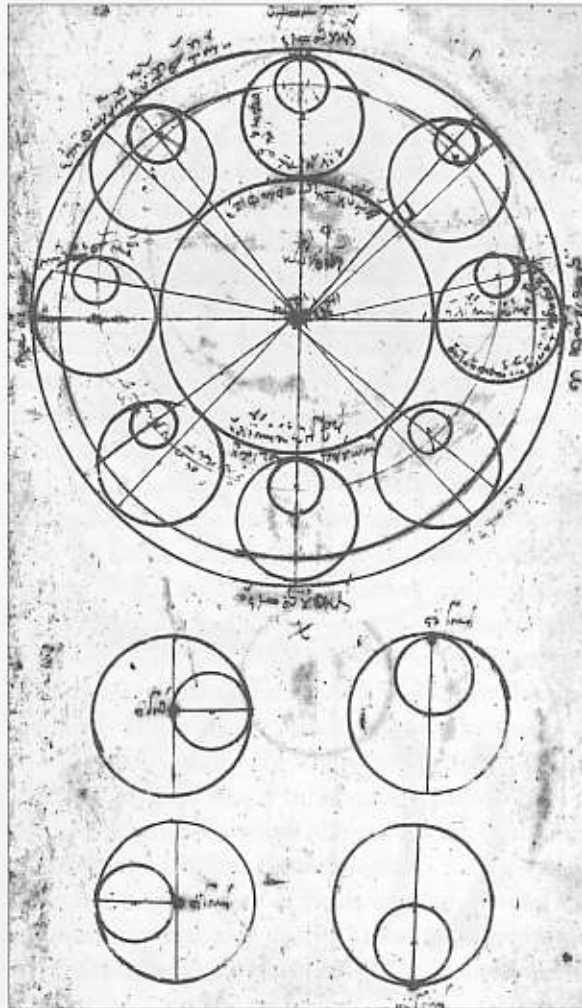


Figure 7. Diagram showing the deployment of the Tusi Couple in a Greek manuscript, Vatican Greek 211, folio 116r, that was brought to Italy after the fall of Constantinople in 1453 AD, and is now kept at the Vatican Library. [Courtesy of Biblioteca Apostolica Vaticana.]

derstood. The second of these theorems, as noted, was left without proof, and Copernicus did not claim either of them as his own. Copernicus therefore must have had some access to these theorems.

There remains the possibility of coincidental discovery, a possibility which both Neugebauer and Swerdlow reject, although others cling to it still. A number of modern researchers believe that they will eventually find similar theorems in the Latin works that would have been available to Copernicus, and hope to thus explain Copernicus' development of his

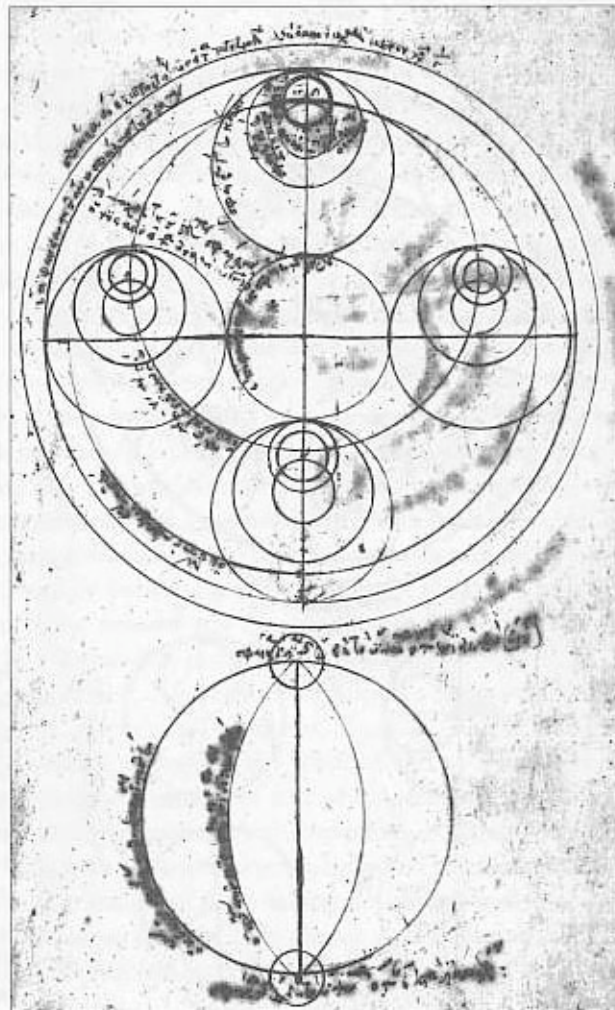


Figure 8. More illustrations from the same Greek manuscript, Vatican Greek 211, folio 117r, showing the similarities with Arabic astronomical drawings. [Courtesy of Biblioteca Apostolica Vaticana.]

ideas independently of the Arabic astronomical tradition. Some evidence along these lines for coincidental discovery of the Tusi Couple is worth serious consideration, but no one has so far established any credible precedent for the 'Urdu Lemma.¹¹

This then is what we know of the similarities between the astronomical theories established in the lands of Islam and those reached by Copernicus at the beginning of the European Renaissance.

OTHER STRIKING SIMILARITIES

Other areas of science include instances where a theory described in Arabic writings reappears a few centuries later in Latin texts. The pulmonary circulation of the blood was first described in Arabic by Ibn al-Nafis about 1243, and then later by Servetus in 1553 in Spain, by Colombo in 1559 in Cremona, Italy, and, finally, by Harvey in 1657 in England.¹² Another example is the decimal point, first noted in the Latin literature in the work of Francesco Pellos (fl. 1450-1500), and later developed into a full-fledged system of decimal fractions by Stevin around 1600.¹³ But recent work by Roshdi Rashed in Paris demonstrates that the decimal point was already used in an Arabic arithmetical text written before 952 AD, and the whole system of decimal fractions was fully developed toward the end of the same century by Karaji, and then by his successor al-Samaw'al in the twelfth century.¹⁴ By the 1420s, a third Arabic-writing mathematician, Kashi (d. 1429), had also efficiently used the decimal system.¹⁵ Similar observations concerning the intellectual contacts between the Islamic world and the Latin West both during and immediately before the Renaissance have been made by George Makdisi in his study, *The Rise of Humanism in Classical Islam and the Christian West*.¹⁶ In literature, authors have discussed the similarities between the works of both Dante and Boccaccio and earlier Arabic works.¹⁷

In sum, in a variety of fields we find striking similarities between material available in Latin manuscripts written after the thirteenth century, during or immediately after the

Renaissance, and material available in much earlier Arabic sources. The puzzling thing is that these materials do not seem to have been translated into Latin in between.

The conventional wisdom among scholars of this pre-Renaissance period is that during the rise of Western science, Arabic science was in decline. This view holds, therefore, not only that the Islamic world was not producing original works of significance after the thirteenth century but that European Renaissance scientists did not seek knowledge from the Islamic world and that contact between the two ended by the 1200s. My recent research indicates that this view may not be accurate.

My research must be seen within the framework of the political situation in Europe and the eastern Mediterranean on the eve of the Renaissance. Prior to the Renaissance, European civilization in general and the Catholic church in particular had been traumatized by a series of events, including the eleventh century split of the Eastern church of Byzantium from the church in Rome, and the Crusades from the eleventh to the thirteenth centuries, which ended in defeat at the hands of Salah al-Din and his successors, and the fall of Constantinople in 1453. As a result, Europe entered a period of deep soul-searching. This process of reassessment produced councils to reconstitute the Catholic church such as that of Basel in 1431-1448 and of Ferrara in 1438.¹⁸ These councils reflected a deeply felt need to reestablish contact with the Eastern Christian churches, which were themselves seeking the aid of Rome after the Crusaders' debacle in which they were to some extent involved. The councils also reflected a perceived need to avert the threat of Islam which was symbolically heightened by the fall of Constantinople.

ARABIC MANUSCRIPTS IN EUROPE

As noted, modern scholars viewed Greek texts as possible transmitters of ideas from the Islamic world to Europe. Research efforts along these lines were reasonably rewarded by such discoveries as the Vatican manuscript in Greek, which contained one of the theorems used by Copernicus. The implicit moti-

vation for this research direction was the assumption that Copernicus could read Greek but not Arabic. The broader prevailing assumption was that Renaissance men did not attempt to read Arabic manuscripts and thus could not have made the contents of these manuscripts available to the Latin West. After all, it was supposed, Western contact with Islamic civilization had ended by the thirteenth century.

My research indicates, however, that there were many Arabic manuscripts available in Italy and in other European centers of learning and many scholars were translating them well into the sixteenth and the seventeenth centuries. Clearly interest in Arabic science remained alive, and contact between at least Italian scholars and the eastern lands of Islam continued long after the 1200s.

My research led me to investigate an Arabic manuscript now kept at the Laurentiana Library in Florence which was described in the library's eighteenth-century catalog as a treatise on theoretical astronomy by the philosopher al-Farabi (d. 950).¹⁹ As I read it, I began to doubt that it was in fact written by al-Farabi whose work I was familiar with from Arabic texts. Having decided that the catalogue was in error regarding this manuscript, I began to wonder what other errors it might harbor.

I decided to survey the scientific collection of the Laurentiana Library, focusing specifically on the mathematical sciences. What I found was a proliferation of names of Italian Orientalists who lived during the 1500s and who were competent enough in languages to read, interpret, and even translate Arabic scientific manuscripts into Latin or Italian, and thus to make their contents available to the Latin West, without necessarily translating them in toto.

LAURENTIANA FINDINGS

The man who completed and in 1742 published the catalogue of the Laurentiana's Oriental collection was a cleric named Stephanos Evodivus Assemanus. He was trained in neither mathematics nor astronomy nor did he know what we now know about the transmission of concepts of theo-

retical astronomy from the Islamic world to Europe. His name indicates that he was one of the Maronite Eastern Christians of Lebanon, many of whom traveled to Rome after their church resubmitted itself to the authority of the Pope towards the mid-1400s.²⁰ By 1567, Maronites had their own school sponsored by the Holy Office in Rome. Assemanus' name, before it was Latinized, was Istiphan 'Awwad al-Sim'ani (1711-1782). His maternal uncle, Guiseppe Simonio Assemanus (Yusuf Sham'un al-Sim'ani, 1687-1768), was the curator of the Vatican Library during the early part of the eighteenth century and was also a cleric. The uncle was sent

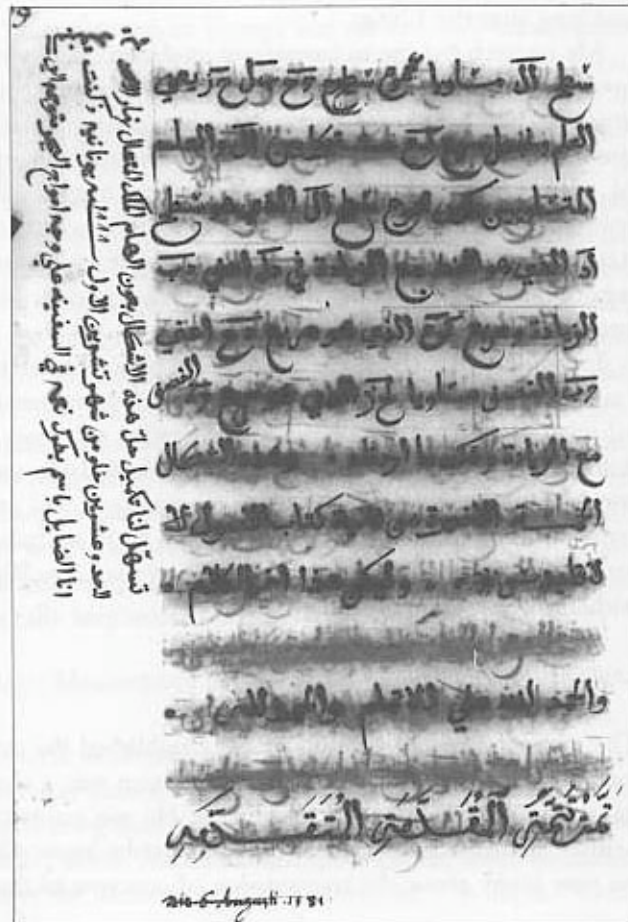


Figure 9. Colophon inserted by Patriarch Ni'meh on the margin of an Arabic manuscript now kept at the Laurentiana library (Orientalia 177, folio 79r) where he says that he was on his way to Venice in the year 1577. [Courtesy of the Laurentiana Library.]

to Rome at the age of eight to study for clerical service, and was supposed to return to Lebanon, where the Papacy had already regained a foothold. Both Assemanus worked at one time or another as curators of the Oriental collection of the Apostolic Library of the Vatican. It was in that capacity that the nephew was called upon to catalogue the Oriental collection of the Laurentiana. This catalogue was started by Petrus Benediktus (also spelled, "Benedetti"), another Lebanese Maronite whose Arab name was Butrus Mubarak (1663-1742), but Assemanus completed it without giving credit to Mubarak.²¹

My survey of the mathematical portion of the collection revealed that the eighteenth-century catalogue was correct 50 to 60 percent of the time. It was in the 40 to 50 percent incorrectly catalogued that I hoped to find important astronomical manuscripts that have gone unnoticed.

On one manuscript dealing with elementary practical geometry, there was the following notation: "I completed the solution of these problems on Sunday, Oct. 21, 1577, while I, the poor wretched Patriarch Ni'meh, was on a ship being tossed by sea waves on my way to Venice"²² (figure 9). To this manuscript are appended several other astronomical treatises, all bearing comments in the hand of the same Patriarch, all dated between 1571 and 1581.

This "poor wretched Patriarch Ni'meh" was, in fact, the Patriarch of a Syriac Jacobite sect, whose see was in the city of Amid near the modern city of Diyarbakir in eastern Turkey. During his tenure, he was engaged in a dispute with the local Muslim officials and accused of atheism.²³ Fearing for his life, he declared his conversion to Islam, thus infuriating his Christian followers. Patriarch Ni'meh subsequently appointed his nephew to his patriarchal see, and escaped to Venice, and from there to Rome. Since his church was not united, the church of Rome welcomed him as a prodigal son who had repented and promised to help bring his church back under the Papal flag.

This Patriarch was apparently a learned man. Another manuscript bears his original composition regarding the computation of the dates of Easter and the movable feasts. He

also left his mark on a third manuscript dealing with elementary astronomy.

Another manuscript, a copy of Euclid's *Elements*, Or. 50, was also marked as having been copied in Amid, the see of Patriarch Nîmeh, indicating that he perhaps escaped with his library. More importantly for our inquiry, he must have hoped to find a market for his Arabic manuscripts in sixteenth-century Italy, and indeed found one.

Other manuscripts in the collection had been signed by men whose names indicate they were native Italians, but who were also apparently competent Arabists. On the manuscript attributed to al-Farabi at folio 114v, I found the signature of one Carlo San Giorgio who was either the owner or the reader of the manuscript (figure 10). Since the signature is inside the manuscript I presume he was the reader. While we don't know more about San Giorgio, it is interesting to note that such elementary astronomical texts were apparently being read in earnest in Renaissance Italy.

Another Laurentiana manuscript, Or. 142, contains an

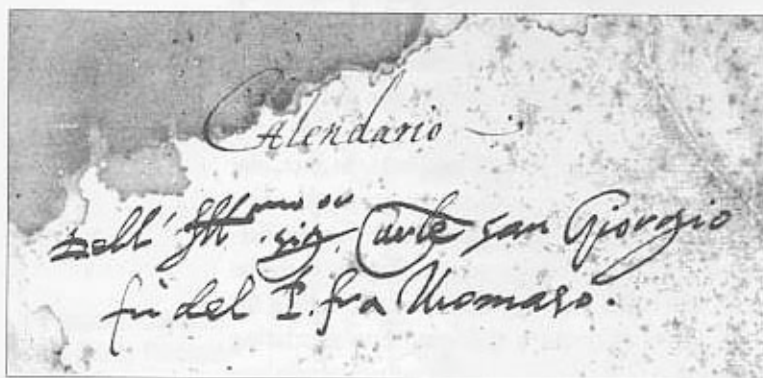


Figure 10. Signature of Carlo San Giorgio on folio 114v of the Laurentiana manuscript *Orientalia* 89. [Courtesy of the Laurentiana Library.]

astronomical work by Tusi, the author of one of the theorems used by Copernicus, but it also includes an Arabic translation of the astrological work of the notorious Raymond of Lull (1232-1316) of Spain, who in his missionary zeal managed to get himself killed in Tunis.²⁴ The Arabic of the trans-

lation is written in Karshuni, a Syriac script, which means that it was intended for use by the Christians whom the Pope was trying to attract back to the Roman church. It is signed by Ya'qub al-Hasruni,²⁵ and Jibra'il al-Qala'i,²⁶ both known from other sources as Arabic-speaking scholars who studied in Rome. Al-Qala'i is at times Latinized, or rather Germanized, as Klahus. Why would the astrology of Raymond of Lull make any sense to the Eastern Christians and why would the manuscript end up at the Laurentiana?

Another, more serious, astrological manuscript, Or. 94, is signed on the flyleaf by its owner Giovanni Battista Raimondi (1536-1614)²⁷ (figures 11 and 12). Raimondi was born in Napoli, traveled to the Middle East around 1575, was interested in mathematics and Oriental languages, taught Arabic in Rome in the late 1500s, and was the director of the Medici Oriental Press from 1584 to 1614. This press was first set up by Cardinal Ferdinand de Medici, but Raimondi bought it for 25,000 scude.²⁸ Like a good academic Raimondi bankrupted the business. The astrological manuscript contains several Latin and Hebrew annotations, presumably by Raimondi.

The fact that Raimondi knew Arabic well enough to teach it and to use it on his travels in the Orient is relevant because it raises this crucial question: in sixteenth-century Italy, who taught him the language? We know that Raimondi was interested not only in Arabic but in mathematics as well. This interest in Arabic and science is reflected in the choice of texts that the Medici Oriental Press published. All this makes some sense when we remember that during Raimondi's lifetime Pope Gregory XIII was seeking help with reforming the Julian calendar, a reform which was implemented officially on October 15, 1582, thus giving us the current Gregorian calendar reckoning. Manuscript Or. 116 contains tables of Turkish calendars, useful in determining the length of years, a factor that would have had to be considered in a calendar reform.

More importantly, manuscript Or. 116 also contains a text on theoretical astronomy which severely criticizes Ptolemaic astronomy and contains both of the theorems that were



Figures 11 and 12. Signature of Gio[vanni] Batt[ista] Raimon[di] on the first page (above) and at the end (below) of the Laurentiana manuscript Orientalia 94. [Courtesy of the Laurentiana Library.]



used by Copernicus. In addition, manuscript Or. 116 is signed by Raimondi, and is noted as having been donated by Camillo Rinoccini (figure 13). It would be enlightening to determine who Rinoccini was, and how long he had this manuscript in his possession before he passed it on to Raimondi. Specifically, it would be relevant to know whether the manuscript was available in Italy during the earlier part of the century when Copernicus was also there. This is the kind of manuscript that could turn out to be key in the story of the transmission of non-Ptolemaic ideas to Copernicus. But more needs to be known regarding its provenance before we can draw such conclusions from it.

Manuscript Or. 218, dated 1581, not only contains a commentary in Arabic on the *Conics* of Apollonius (230 B.C.), but includes interlinear notes and word-for-word translations in Italian. The original Arabic composition of this commentary is by Abu al-Fath of Esfahan (fl. 1128) and is preserved in Laurentiana manuscript Or. 118, which was in turn copied by the famous astronomer Qutb al-Din al-Shirazi (d. 1311) who was a student of Tusi. Whoever was using this commentary on the *Conics* in sixteenth-century Italy certainly was not possessed by a zeal to retrieve the Greek text of classical antiquity, as we have been led to believe Renaissance scientists would have done, for Abu al-Fath's commentary contains no such text. Whoever annotated and partially translated this manuscript was trying to study the *Conics* through this Arabic commentary with the help of a teacher. The language of instruction was apparently Italian.

Imagine the possibility of a similar situation when Copernicus was in Italy. Perhaps he had the opportunity to study one of the critiques of Ptolemaic astronomy that were available in Arabic theoretical astronomical texts from as early as the thirteenth century and which are still preserved in European collections today.

Manuscript Or. 375 deals with physiognomy and is explicitly annotated as having been bought by (*comprato dal*) "Sign.or Gerolamo Vecchiotti" in Egypt for "Gio. Batt.a Raimondi." We have no date of purchase, but from other sources, partly supplied by Giovanni Nencioni, the current

president of the Accademia della Crusca in Florence, we know that this same Vecchietti was interested in theology and in calendar reform. We also know that he traveled with his brother Giambattista Vecchietti (1552-1619),²⁹ whose letters we have from the Persian city of Hurmuz in 1587, and from Goa in India in 1588.³⁰

Manuscript Or. 450, on the workings of astrolabes, was apparently owned by "Monsignor Pat.ca," whose identity is not known to me. Astrolabes, however, were very useful astronomical instruments and were obviously used in Italy. I have demonstrated elsewhere that a drawing executed in about

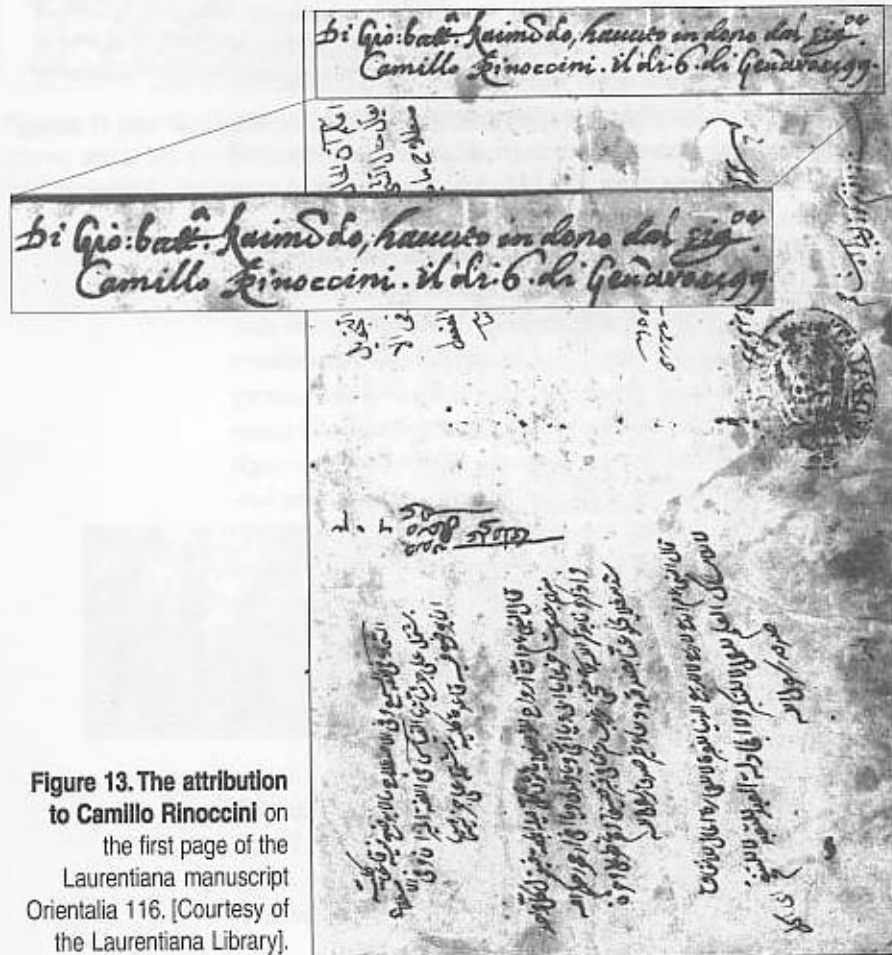


Figure 13. The attribution to Camillo Rinoccini on the first page of the Laurentiana manuscript Orientalia 116. [Courtesy of the Laurentiana Library].

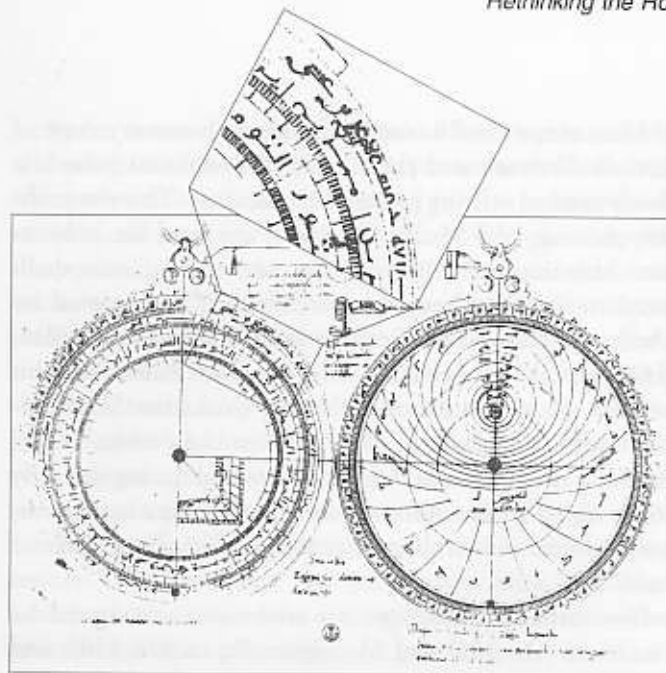


Figure 14. A drawing of an astrolabe, which was originally made in Baghdad around 850 A.D. by Khafif the student of 'Ali b. 'Isa (clearly inscribed on the upper right hand rim of the drawing on the left). The drawing was executed by Antonio de Sangallo the Younger, the architect of St. Peter's, about 1520.

[Courtesy of Professor Gustina Scaglia, NY.]

1520 A.D. by Antonio de Sangallo the Younger (a Florentine architect who built the greater part of St. Peter's in Rome) was of an astrolabe made in Baghdad around the year 850 A.D.³¹ (Figure 14). Monsignor Pat.ca also owned a manuscript, Or. 416, dealing with quadrants—a more developed form of astrolabe—which confirms the owner's interest in Arabic astronomical instruments.

Manuscript Or. 106, containing astronomical tables useful for determining positions of planets, was also signed by "Vecchietti," whom I assume was the same Gerolamo Vecchietti who was interested in calendar reform.

Manuscript Or. 22 contains a series of texts that derive ultimately from the Greek. But the Arabic translations were revised and edited by the astronomer Tusi, who in 1247 conceptualized one of the two theorems used by Copernicus. The manuscript itself was copied by a deacon at Amid, and probably formed part of the library of the Patriarch Ignatius Ni'meh mentioned above.³² Another manuscript signed by the Patriarch, Or. 27, contains freshly drawn calendars for Easter and the movable feasts. The manuscript was likely written in Venice, for it contains references to the longitude of that city.

Manuscript Or. 20 contains a sixteenth-century copy of Euclid's *Elements*, and the *Conics* of Apollonius, which is clearly marked as being prepared for the press. This was probably the copy the Medici Oriental Press used for publication. Manuscript Or. 38 is another copy of the *Conics*, dedicated to Cardinal Leopoldo de Medici,³³ and copied by Abrahamo Ecchellensis. Ecchellensis is Ibrahim al-Haqillani (1605-1665)³⁴ of Lebanon, who lived in Rome with his nephew Giovanni Matteo Naironi (Yuhanna Matta al-Namrudi?).³⁵ Ecchellensis taught Syriac and Arabic, first in Paris and then in Rome,³⁶ and collaborated during the early 1600s with Giovanni Alfonso Borelli to produce a Latin translation from the Arabic commentary on the *Conics* of Apollonius.

Two other manuscripts on arithmetic are signed by Vecchietti (Or. 361) and Monsignor Pat.ca (Or. 450), and constitute further evidence of the kind of books scholars were bringing into Italy.

CONCLUSIONS TO BE DRAWN

What do these findings tell us about the transmission of astronomical ideas from the Islamic world to the world of Copernicus? First, the sheer number of Arabs in Italy, and the number of Italians who knew Arabic, taught Arabic, and traveled to the Orient during the 1500s is impressive. During that time Italy seems to have been in close contact with the Islamic world.

Second, as late as the late 1500s and the early 1600s, science, even in the form of elementary treatises on mathematics and astronomy, was still being sought from Arabic sources, as the Laurentiana collection demonstrates. One can reasonably assume that scientists who were still in need of elementary astronomical and mathematical texts that late in the 1500s would have been in still greater need of similar scientific texts earlier in the century. That there was such a demand for scientific texts from the Islamic world implies much more extensive contact with that region than has hitherto been assumed.

As for contact between Copernicus and Arabic material critiquing Greek astronomy, and in particular the two essential mathematical theorems required for the reconstruction of such critiques, my findings might at first glance appear disappointing, since the manuscripts I examined date from the latter part of the sixteenth century, after Copernicus produced his *De Revolutionibus*. But close examination of the material reveals that these manuscripts were owned by people who lived in the latter part of the sixteenth century and who knew Arabic, and knew it well enough to translate texts interlinearly, to prepare them for the press, or to cooperate in producing sophisticated Latin editions. Who taught these scholars Arabic? Who were Raimondi and Vecchietti's professors? Once we realize that the teachers must themselves have been contemporaries of Copernicus, the evidence begins to look more promising.

Furthermore, now that we can determine ownership of the manuscripts, we can reasonably ask who owned the books before they came into the possession of these Italian scholars. Were they already in Italy when Copernicus was there? Could they have been consulted for the calendar reform, a project started under Popes Julius II and Leo X in the early 1500s? Perhaps by accident these manuscripts acquired and/or consulted for the calendar project were found to contain critiques of Ptolemaic astronomy and the two famous theorems that went with it. These two Popes were not only seriously interested in calendar reform³⁷ but also developed the first Arabic press in Fano on the western shore of the Adriatic in 1514.³⁸ Moreover, Copernicus himself had some interest in reforming the calendar, advising Paul of Middelburg around the same year on the topic.³⁹ It was Paul who, at the urging of Popes Julius and Leo, brought his calendar reform project to the Lateran Council, but failed to convince the Council to adopt it. This reform had to wait until the time of Gregory XIII in 1582.

From early on, therefore, patrons of Arabic language presses in Italy seem to have been interested not only in religious texts, as is commonly thought. Nor do I think that their sights were set solely on the Arab world market. Of the first

six books published by the Medici Oriental Press between 1591 and 1595, four were on scientific topics. This press, for example, printed 1,967 copies of Euclid's *Elements*. By comparison, they printed only 566 copies of the Bible in Arabic.⁴⁰ As for the market for these scientific texts, it is sufficient to note that Raimondi, the director of the Medici Press, towards the end of the 1500s still felt that he should produce an Italian interlinear translation of the work of the popular Arabic-writing scientist Shams al-Din al-Samarqandi on elementary practical geometry. The codex containing Raimondi's translation is preserved⁴¹ with other manuscripts from his collection at the National Library of Florence.⁴² Such interlinear translations must have been for the benefit of Italian students.

If we look a little closer at the period before the sixteenth century, and especially at the fifteenth century just before the arrival of Copernicus in Italy, we find a treasure in the work of Gubernatis, cited earlier. He lists a group of Italians who knew Arabic dating back to the 1200s. One can add to that list the Florentine Ricoldo da Monte Croce who apparently went to Baghdad around 1290, studied Arabic, and produced a Latin polemical work against Islam which later interested Martin Luther himself, for Luther translated it into German in 1542.⁴³ In the 1400s we find someone like the Venetian physician Andrea Alpago, also known as de Belluno (d. 1521), who was so dissatisfied with the medieval Latin translations of the Arabic-language medical works of Avicenna that he traveled to Syria where he lived for nearly 30 years and produced, among other things, fresh Latin translations of Avicenna's *Canon* and parts of the commentaries on that *Canon*. He returned to Venice to serve the government as a professor of medicine at the University of Padua.⁴⁴ He may well have met Copernicus there when the latter was a student at the nearby University of Ferrara. An educated man such as Andrea Alpago who had lived in Syria for some 30 years would certainly have learned of the so-called new astronomy of the Damsacene Ibn al-Shatir, whose concepts were by then already more than 100 years old.

One of the texts translated into Latin by Alpago con-

tained the description of the pulmonary motion of the blood referred to above, although that portion no longer exists in his translation. We can, however, surmise that he knew about it. A copy of the original Arabic of the text was brought to Italy and still exists at the University of Bologna library under the number "Arabic, 3541."⁴⁵ When was this manuscript brought to Italy, and who read it there? Were the contents made available to scientists such as Servetus and Colombo, and later to Harvey?

Another Venetian physician, Hieronimo Ramusio, also traveled to the Islamic world and produced a Latin translation from Arabic of a great part of the works of Avicenna. He died in Beirut in 1486.⁴⁶

My current research demonstrates that Guillaume Postel (d. 1581), a younger contemporary of Copernicus and a frequent visitor to Italy, sought Arabic manuscripts as well. He annotated these manuscripts and may very well have used them for his lectures at the Royal Institute (now the Collège de France), where he taught mathematics and Oriental languages.⁴⁷ One of those manuscripts, Arabo 319, is now at the Vatican Library. The manuscript is a copy of Tusi's *al-Tadhkira fi 'ilm al-Hay'a* (*Memoir on Astronomy*) that contains the Tusi Couple (figure 15). The *Memoir* was once owned by Postel and most probably annotated by him: it is practically certain that the marginal notes are in his hand⁴⁸ (figure 16).

Another Arabic manuscript, Arabo 2499, dealing with planetary theories, now housed at the Bibliothèque Nationale in Paris, was also owned by Guillaume Postel. It is clearly marked on its title page "ex libris Guilielmi Postelli" (figure 17). This manuscript carries a date in Postel's hand, Constantinople 1536 (figure 18). This may indicate that Postel himself bought the manuscript during one of his many trips to the Orient. The colophon also seems to indicate another place and date, Damascus 1537, which may mean that Postel spent at least those two years in the Orient. More research needs to be done on the connection between Postel and Arabic manuscripts still preserved in various European libraries to determine the provenance of such texts, and their



Figure 15. The Tusi Couple as it appears in the Vatican manuscript, Arabo 319, folios 28v-29r. [Courtesy of Biblioteca Apostolica Vaticana.]



Figure 16. The marginal notes on the Vatican manuscript, Arabo 319, fol. 14v, made by Guillaume Postel. [Courtesy of Biblioteca Apostolica Vaticana.]

whereabouts in Europe during the time that Copernicus was learning of the new Arabic astronomy from which he ultimately derived the two crucial theorems.

Among the other players who participated in the transmission of Arabic science to Europe during the Renaissance is Leo the African (al-Hasan b. Muhammad al-Wazzan). Al-Wazzan was born in Granada in 1485, captured by pirates in 1518, and given to Pope Leo as a slave. He converted to Christianity and took the name of his master, but converted back to Islam in 1529 when he returned to Tunis, where he died in 1554. This man was well educated and produced

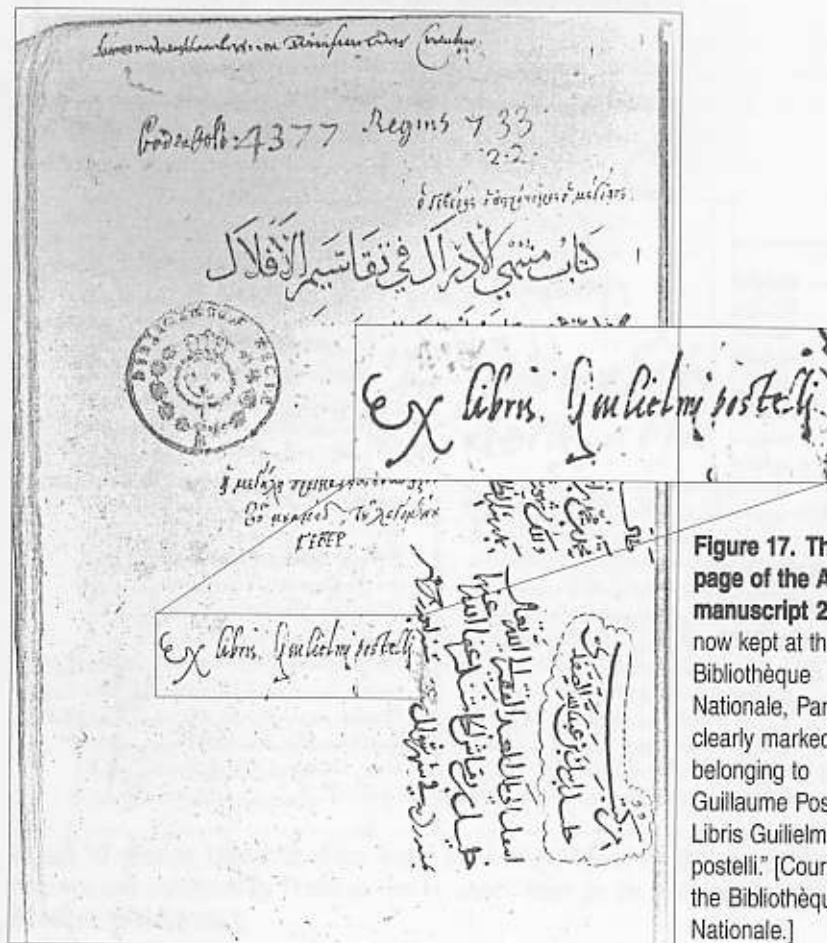


Figure 17. The first page of the Arabic manuscript 2499, now kept at the Bibliothèque Nationale, Paris, clearly marked as belonging to Guillaume Postel: "Ex Libris Guilielmi postelli." [Courtesy of the Bibliothèque Nationale.]

original works on scientific geography in Italian but based on Arabic sources.⁴⁹

THE ROAD AHEAD

What we can tentatively assert on the basis of the Laurentiana Library evidence is that there was no shortage of Arabic manuscripts in Italy nor of men who were interested in their content and were still translating them well into the sixteenth and seventeenth centuries. As far as earlier centuries are concerned, and the early part of the 1500s in particular, when

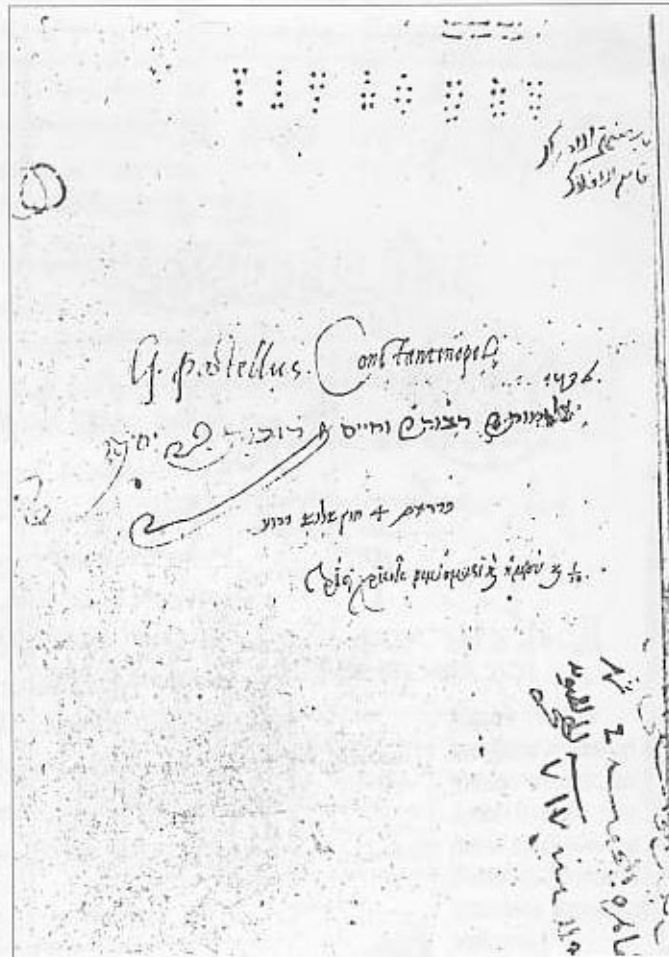


Figure 18. A flyleaf of the Arabic manuscript 2499 of the Bibliothèque Nationale, Paris, marked by Postel as having been bought in Constantinople in the year 1536. [Courtesy of the Bibliothèque Nationale.]

Copernicus could have benefitted from this transmission of ideas from the Islamic world to the West, further research into the collections of Arabic manuscripts still preserved in Italy and the rest of Europe may well bring a more complete story to light (figure 19).

A careful study of the Arabic manuscript collections extant in Italy may not only open new routes for investigating the possible contact between Copernicus and the earlier astronomers who wrote in Arabic, but may begin to give us a clearer picture of the kind of science that was practiced in Renaissance Italy and the relationship of that science to Arabic science. Only then may we understand the works of the Italian astronomers who were the contemporaries of Copernicus.

If Renaissance science can be concretely shown to have been so seamlessly blended with Arabic science, should not this in itself change the current periodization schemes re-



Figure 19 : Folios 112v-113r of the Arabic manuscript 2499 of the Bibliothèque Nationale, Paris, heavily annotated by Postel as can be clearly seen on the margins. [Courtesy of the Bibliothèque Nationale.]

garding the Middle Ages, the translation period from Arabic into Latin, and the very nature of science and scientific activities during the Renaissance?

ENDNOTES

1. For the works of Neugebauer on the relationship of Arabic to Copernican astronomy, see his earliest mention of it in 1957 in Otto Neugebauer, *The Exact Sciences in Antiquity* (Providence: Brown, 1957), pp. 204 ff, to which he returned in 1968 in Otto Neugebauer, "On the Planetary Theory of Copernicus," *Vistas in Astronomy*, vol. 10 (1968), pp. 89-103, esp. pp. 94-95. Kennedy's work on the subject is now conveniently available in the form of collected articles in E.S. Kennedy and Colleagues, *Studies in the Islamic Exact Sciences* (Beirut: American University of Beirut, 1983), pp. 50-107.
2. Noel Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory: A Translation of the Commentariolus and Commentary," *Proceedings of the American Philosophical Society*, vol. 117 (1973), pp. 423-512, esp. p. 469.
3. Willy Hartner, "Copernicus, the Man, the Work, and its History," *Proceedings of the American Philosophical Society*, vol. 117 (1973), pp. 413-22.
4. George Saliba, "Arabic Astronomy and Copernicus," *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften*, vol. 1 (1984), pp. 73-87.
5. Anthony Grafton, "Michael Maestlin's Account of Copernican Planetary Theory," *Proceedings of the American Philosophical Society*, vol. 117 (1973), pp. 523-50.
6. Noel Swerdlow and Otto Neugebauer, *Mathematical Astronomy in Copernicus's De Revolutionibus* (New York: Springer, 1984), p. 295.
7. People usually forget that the cosmological justification for heliocentricity came only a century or so later when universal gravitation among celestial bodies became better understood.
8. I recently surveyed astronomical writings on Arabic planetary theories from this period in two works. See George Saliba, "Arabic Planetary Theories after the Eleventh Century AD," *Encyclopedia of the History of Arabic Science* (London: Routledge, 1996), pp. 58-127; and *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam* (New York: New York University Press, 1994).
9. George Saliba, "Early Arabic Critique of Ptolemaic Cosmology: A Ninth-Century Text on the Motion of the Celestial Spheres," *Journal for the History of Astronomy*, vol. 25 (1994), pp. 115-41.
10. Neugebauer first made reference to the Greek manuscript, Vat. Gr. 211, in his monumental *History of Ancient Mathematical Astronomy* (New York: Springer, 1975), plate IX, where a facsimile of folio 116r of the manuscript is published, and again in his joint work with Swerdlow, *Mathematical Astronomy*, where both folios 116r and 117r of the same manuscript are published.
No Latin description of these theorems has been located but several people are looking into that possibility. See Mario Di Bono, "Copernicus, Amico, Fracastoro and Tusi's Device: Observations on the Use and Transmission of a Model," *Journal for the History of Astronomy*, vol. 26 (1995), pp. 133-54.
11. See Saliba, "Arabic Astronomy and Copernicus."
12. For the literature on Ibn al-Nafis, see Albert Iskandar in the *Dictionary of Scientific Biography*, vol. 9 (1974), pp. 602-06.
13. For a very brief mention of the decimal point including the Latin West, see Carl Boyer, *A History of Mathematics* (Princeton: Princeton University Press, 1985), p. 307; and A.S. Saidan in *The Arithmetic of al-Uqlidisi* (Boston: Reidel, 1978), pp. 481-85.
14. The first person to establish the precedence and to produce a translation of the Uqlidisi text

in which the decimal point is first utilized, was Saidan, pp. 481-85. For the most recent treatment of the history of the decimal fractions in the Arabic sources and their possible transmission to the Latin West, see Roshdi Rashed, "Combinatorial Analysis, Numerical Analysis, Diophantine Analysis and Number Theory," *Encyclopedia of the History of Arabic Science*, vol. 2 (London: Routledge, 1996), pp. 376-417, esp. pp. 389-91.

15. On this mathematician, see A.P. Youschkevitch and A.B. Rosenfeld in *Dictionary of Scientific Biography*, vol. 7 (New York: Scribner, 1973), pp. 255-62.

16. George Makdisi, *The Rise of Humanism in Classical Islam and the Christian West* (Edinburgh: Edinburgh University Press, 1990).

17. On these connections see the most recent treatment by Paul A. Cantor, "The Uncanonical Dante: The Divine Comedy and Islamic Philosophy," in *Philosophy and Literature*, vol. 20 (1996), pp. 138-53, esp. note 5, where he makes reference to earlier works on the subject. Also see the short reference made by R.A. Nicholson, in the chapter on mysticism in Sir Thomas Arnold and Alfred Guillaume, eds., *The Legacy of Islam* (Oxford: The Clarendon Press, 1931), p. 227. On Boccaccio see the tentative conclusions drawn by Dorothee Metlitzki, *The Matter of Araby in Medieval England* (New Haven: Yale University Press, 1977), p. 151f. See also H.A.R. Gibb in the chapter on literature in *The Legacy of Islam*, p. 193.

18. For a discussion of the problems that gave rise to these councils and the awareness in Europe of the Turkish danger see, among others, A.A. Vasiliev, *History of the Byzantine Empire* (Madison: University of Wisconsin, 1971), pp. 672-74, and Asad Rustum, *Kanisat Madinat Intakiyah al-'Uzma*, vol. 2 [Arabic with English title: *The Church of the City of God Great Antioch*] (Beirut: Edition St. Paul), pp. 360-62.

19. The treatise in question is Or. 89, designated by Stephanus Evodivus Assemanus in *Bibliothecae Mediceae Laurentianae et Palatinae codicum mss orientaliu catalogus* (Florentiae [Florence]: Typographio Albiginiano, 1742), p. 395, as being the work of al-Farabi.

20. Louis Sheikho, S.J., "al-Ta'ifa al-maruniya wa-l-ruhbania al-yasu'iya fi al-qarnayn al-sadis 'ashar wa-l-sabi' 'ashar," *Mashriq*, vol. 17 (1914), p. 323.

21. This information was brought to my attention in 1994 by one of the descendants of Mubarak, who in 1994 was the Lebanese permanent representative to the United Nations. For a biography of Mubarak, see Georg Graf, *Geschichte der Christlichen Arabischen Literatur*, Bd. III (Studi e Testi, Bibliotheca Apostolica Vaticana, 1947-1953), p. 389f. Graf does not mention the catalogue, but he does say that Mubarak worked in Toscana and taught Biblical studies at Pisa.

22. Laurentiana, Or. 177, fol. 79r.

23. He was ordained in 1555. See Louis Sheikho, S.J., *Mashriq*, vol. 19 (1921), p. 139, and Rustum, vol. 3, p. 27.

24. Gerhard Endress, *Introduction to Islam*, trans. by Carole Hillenbrand (Edinburgh and NY: Edinburgh University Press and Columbia University Press, 1988), p. 7.

25. See Sheikho, *Mashriq*, vol. 19 (1921), p. 144.

26. Graf, *Geschichte*, pp. 309-33.

27. Guglielmo Enrico Saltini, *Giornale Storico Degli Archivi Toscani*, vol. 4 (1860), pp. 257-308.

28. Fernanda Ascarelli and Marco Menato, *La Tipografia del 1500 in Italia* (Florence, 1989), pp. 129-30.

29. See Angelo Maria Bandini, *Dei Principi e Progressi della real Biblioteca Mediceo Laurenziana* (Florence: Edizioni Gonnelli, 1990), p. 74.
30. See Ettore Marcucci, *Lettere edite e inedite di Filippo Sassetti* (Florence: Felice le Monnier, 1855), pp. 402-3. (This reference was brought to my attention by Giovanni Nencioni, President of Accademia della Crusca, July 1994.)
31. George Saliba, "A Sixteenth-Century Drawing of an Astrolabe Made by Khafif Ghulam 'Ali b. 'Isa (c.850 A.D.)," *Nuncius, Annali di Storia della Scienza*, vol. 6 (1991), pp. 109-19.
32. The curious part about this manuscript is that all the laudatory references to Prophet Muhammad that form the usual endings of Arabic manuscripts are crossed out here with a different ink. My guess is that the censorship was probably done by the Patriarch himself in order to prove his good repentance back to Christianity or by Raimondi to avoid censorship. But that is only a guess, and I have no way of demonstrating that one way or the other.
33. On Leopoldo de Medici and Ecchellensis, see Mario Emilio Cosenza, *Biographical and Bibliographical Dictionary of the Italian Humanists and of the World of Classical Scholarship in Italy 1300-1800* (Boston: G.K. Hall and Co., 1962), pp. 2276 of vol. 3 on Leopoldo and p. 4 of vol. 1 on Ecchellensis.
34. G. Levi della Vida, *Ricerche sulla formazione del più antico fondo dei manoscritti orientali della biblioteca Vaticana* (Vatican City: Biblioteca Apostolica Vaticana, 1939 [Studi e Testi 92]), p. 6, n. 3.
35. *Ibid.*, p. 6, n. 4.
36. See G. Garollo, *Dizionario Biografico Universale* (Milan: Ulrico Hoepli, 1907), p. 719.
37. See W.F. Bynum, et al., *Dictionary of the History of Science* (Princeton: Princeton University Press, 1984), p. 50.
38. See Angelo de Gubernatis, *Matériaux pour servir à l'histoire des études orientales en Italie* (Paris: Ernest Leroux, 1876), p. 188.
39. Swerdlow and Neugebauer, *Mathematical Astronomy*, p. 31.
40. Saltini, *Giornale Storico*, p. 293, n. 2.
41. Saltini, *Giornale Storico*, p. 303, cod. IX.
42. See Renato Traini, "I Fondi di manoscritti Arabi in Italia," in *Gli Studi Sul Vicino Oriente in Italia dal 1921 al 1970* (Rome: Istituto per l'Oriente, 1971), pp. 221-76, esp. p. 232.
43. Endress, *Introduction to Islam*.
44. Gubernatis, *Matériaux*, pp. 182-84; Iskandar, *Dictionary of Scientific Biography*, p. 604; and Jacob Burckhardt, *The Civilization of the Renaissance in Italy* (New York: Harper, 1958), p. 209.
45. See Le Baron Victor Rosen, *Remarques sur les manuscrits orientaux de la Collection Marsigli a Bologne* (Rome: Imprimerie de l'academie royale des lincei, 1885), p. 95.
46. Burckhardt, *The Civilization of the Renaissance*, p. 209; and Gubernatis, *Matériaux*, p. 186-87.
47. George Saliba, "Arabic Science in Renaissance France: Guillaume Postel and Arabic Planetary Theories," (forthcoming).
48. Della Vida, *Ricerche*, p. 307.
49. Thomas Glick, "Leo the African," in *Dictionary of Scientific Biography*, vol. 9 (1974), p. 190.



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